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Before the
Federal Communications Commission
Washington, D.C. 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

In the Matter of	)	
	)	
Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules	)	WT Docket No. 99-168

COMMENTS OF MOTOROLA

Motorola hereby files the following comments in the above-captioned proceeding in response to the Commission's Public Notice seeking comment on issues related to the use of spectrum "guard bands" in the 746-764 and 776-794 MHz blocks.[1]

In its recently released *First Report and Order* in this proceeding, the Commission has unanimously created two guard bands located between the newly allocated licenses and the previously allocated public safety spectrum in the 764-776 MHz and 794-806 MHz bands. The Commission was motivated to create the guard bands in order to comply with the Congressional requirement contained in the Balanced Budget Act of 1997 to "*ensure* that public safety licensees continue to operate free of interference from any new commercial licensees."[2] The time has now come for the

[1] *Public Comment Sought on Issues Related to Guard Bands in the 746-764 MHz and 776-794 MHz Spectrum Block,* WT Docket No. 99-168, *Public Notice,* (released Jan. 7, 2000). Motorola has limited its comments herein to the technical and operational issues raised in the Commission's Public Notice.

[2] Balanced Budget Act of 1997, Conference Report to accompany H.R. 2015, 105th Cong., 1st Sess., Report 105-217, at 580 (July 30, 1997) (emphasis supplied).

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Commission to complete its implementation of this Congressional directive by adopting service rules and interference criteria for those guard bands that fully and effectively protect critical public safety operations.

As detailed herein, and as Motorola has exhaustively demonstrated in this proceeding, the Commission cannot comply with Congress' directive by adopting rules which would allow a subscriber-based cellular architecture in these critical guard bands. <u>There should be no mistake about this point</u>: <u>If the FCC allows subscriber-based cellular architectures access to the public safety guard bands, there will be unacceptable interference on a significant scale to adjacent public safety systems</u>. This is a matter of physics, practicality, and the sheer number of transmitters that will be deployed in close proximity – both geographically and spectrally – to public safety receivers. The proponents of cellular architectures in these guard bands have not demonstrated otherwise.

Motorola has provided answers to the specific questions raised by the Commission's Public Notice in Appendix A. However, Motorola's basic position, as explained throughout this proceeding, may be summarized as follows:

- ***Guard band operations that are technically and operationally similar to public safety systems will meet the Congressional mandate to protect public safety systems – as they have consistently in the past.***

For both the Commission and Motorola, the issue of inter-system interference is not an academic question. As the manufacturer of a broad range of wireless products,[3]

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[3] Motorola is the only party in this proceeding which has actually manufactured, tested, and installed equipment for virtually all of the markets and technology segments

Motorola has a great deal of practical, real-world, first-hand experience in making two-way radio systems used by businesses for internal communications work in bands adjacent to public safety communications. For decades, these user communities have shared spectrum allocations in the 30-50 MHz, 150-174 MHz, 450-470 MHz, 470-512 MHz, and 806-821 MHz bands.

These systems work alongside public safety systems for a number of reasons, but primarily because the relatively high-powered two-way communications systems are operationally and technically similar to the adjacent public safety systems that they protect.[4] As a result, the interference potential is easily predicted and can be compensated for through careful frequency and operational coordination that addresses the transmitter location and transmitting frequencies of the interfering system.[5]

The experience gathered through the deployment of millions of two-way, internal-use radio systems for both public safety and other users not only provides knowledge of what conditions cause interference but also as to how those conditions can be avoided. It

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represented – including public safety, two-way wireless, commercial mobile, and fixed wireless.

4 In one of its numerous *ex parte* filings, FreeSpace Communications, the major proponent of cellular architectures in the guard bands, states that its proposed system technology is superior in terms of public safety interference avoidance because it uses lower power. *Ex Parte Letter of Charles W. Logan*, December 23, 1999, Enclosure at 1. In fact, as demonstrated herein, low-power operational characteristics actually *increase* the potential for interference by geometrically increasing the number of base stations – and, thus, geometrically increasing the number of potential interference points – used to cover a given geographic area. *See* Attachment 1 to Appendix A.

5 To use one example, public safety and internal business communications systems are frequently located at the same transmitter site. This co-location means that any resulting interference to the public safety system will be essentially constant and predictable and, thus, can be compensated for.

also provides a compelling basis for crafting rules that have a very high probability of protecting neighboring public safety operations – thus, "ensur[ing]"[6] that public safety systems are protected.

- ***Subscriber-based cellular architectures are inherently incompatible with public safety operations and allowing them in the public safety guard bands will create a very high probability of unacceptable interference.***

The operational and technical characteristics of subscriber-based cellular architectures are substantially different from public safety systems in ways that create a high probability of interference to public safety systems. Indeed, this incompatibility is the reason for the creation of guard bands in the first place – to keep systems with fundamentally dissimilar operational characteristics spectrally removed from each other.

As suggested above, for typical two-way radio systems of similar configuration, Motorola's and the Commission's experience demonstrates that there potentially could be only one or two interfering base stations inside the coverage area of a single public safety base station. With proper frequency coordination that fully considers the location of each transmitter and its operating frequencies, those interference zones can be eliminated – again, as experience has demonstrated.

However, for cellular architectures that seek to cover a geographic area with a grid-like deployment of interconnected base stations, the density of potential interferers within public safety service areas increases dramatically. For example, assuming hexagonal packing and a typical cell radius of 2.2 kilometers, 64 cell sites would fit

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[6] *See supra* note 2.

within a typical public safety circular service area having a radius of 16 kilometer (10 miles)– *i.e.*, 64 areas in which public safety communications would be compromised.[7]

Based on this architecture and the interference methodology developed by the National Telecommunications and Information Administration (NTIA), the Attachment to Appendix A of these comments calculates the interference zones caused by a cellular-like base station deployment. Even assuming the use of antennas with zero gain,[8] public safety communications will be subject to unacceptable interference in 11.9 square kilometers (approximately 5 square miles) within the 16 kilometer (10 mile) public safety service radius.[9] The predicted areas of interference rise greatly when one considers gain antennas.[10]

Transmissions from subscriber units associated with the base cell sites also dramatically increases the level of potential interference to public safety users.[11] This is particularly problematic if the subscriber units are fixed units mounted on the walls of businesses and residences. Such devices operate at greater heights than a unit operated in a vehicle and, thus, look more like base stations from an interference point of view. In a fixed service deployed in a cellular configuration, all of the potentially thousands of subscriber units would act as interference sources as well, and, of course, as a subscriber-based commercial system, the economic incentive would be to add as many subscribers

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[7] This discussion is fully explained in the Attachment to Appendix A at 3-9.

[8] This is a conservative number. Typical base stations utilize antennas of 6-10 dB gain relative to a standard dipole.

[9] Attachment to Appendix A at 9.

[10] *Id.*

as possible. Moreover, with a service aimed at residences, these interference areas would most likely occur in high population density areas – precisely where public safety officials are most often needed to protect lives and property.

The analysis contained in the attached Appendix quantifies the potential risk to a 16 kilometer public safety service radius. Conservatively calculated, the analysis shows that a huge portion of the public safety service area – as high as 443 square kilometers – would receive potentially interfering signals from commercial subscriber units operating in the guard bands.[12] Accordingly, the number of interference zones created by a subscriber-based system with a cellular architecture cannot be effectively managed through frequency and operational coordination. To the contrary, attempting to layer a cellular architecture with numerous and unpredictable points of interference on top of a fundamentally dissimilar public safety system that requires operational certainty would be virtually impossible.

- ***Proponents of cellular architectures in the public safety guard bands have not demonstrated that their operations would be compatible with public safety operations.***

Given Congress' directive that the Commission "ensure that public safety services licensees continue to operate free of interference from any new commercial licensees,"[13] it is entirely appropriate for the Commission to require that any potential user of adjacent

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11 *Id.* at 9-13.

12 *Id.* at 13.

13 *Id.*

spectrum affirmatively demonstrate, not merely assert, that it could successfully operate so as not to cause interference to critical public safety uses.

Over several decades, various land mobile services – particularly internal-use business and industrial dispatch services – have demonstrated the ability to cohabit frequency bands with public safety without causing significant interference. Both the public safety and business/industrial user communities have benefited through a detailed coordination process that takes advantage of the typical operating characteristics of dispatch systems to avoid mutual interference. In particular, interference is averted because: (1) fewer sites means fewer interference zones to manage, (2) narrower bandwidths are easier to filter; *i.e.*, the interference is not spread across as much spectrum, and (3) internal use systems are not always driven to increase coverage area or subscribers, *i.e.*, system expansion is relatively static because additional users are not needed to increase revenue. Given the number of internal-use systems operating in the existing, relatively small frequency allocations, this coordinated deployment is truly one of the FCC's success stories.

At various times in the last few weeks, proponents of cellular architectures in the public safety guard bands, particularly FreeSpace Communications, have argued that the FCC should not regulate system deployment but, instead, should rely on technical rules such as radiated power and out of band emission restrictions to protect public safety systems. However, FreeSpace has wholly failed to demonstrate the compatibility of its technology with public safety. In fact, FreeSpace has been remarkably coy about the operational and technical details of its system. And what *is* known about the FreeSpace system can give no comfort that FreeSpace's operations would "ensure" non-interference with public safety systems.

FreeSpace has said little about its system. For example, even after its raft of *ex parte* filings,[14] the bandwidth which FreeSpace intends to employ remains unclear to the Commission. Whether the system uses FDD or TDD technology for duplex operations remains a mystery. The Commission is unaware of whether FreeSpace intends to use frequency-hopping spread spectrum techniques. In short, the Commission knows almost nothing that can be used to understand the capabilities of the FreeSpace technology for keeping the promises that FreeSpace has so readily made. In essence, FreeSpace invites the Commission to assume that there will be no interference simply because FreeSpace says there will be no interference. However, the FCC cannot discharge its duty to "ensure"[15] non-interference based on unarticulated or untested "assumptions."

Nor can the FCC derive obtain much comfort from what FreeSpace *has* said about its system over the course of the past few weeks. Indeed, FreeSpace's position has been a freely moving target. For example, FreeSpace's initial plan to protect public safety consisted solely of transmit power limits in the guard bands.[16] When reminded that out-of-band emissions, not in-band power, was the major concern, FreeSpace agreed to conform to the out-of-band emission requirements that Motorola proposed for non-guard band spectrum. When Motorola and law enforcement officials pointed out that frequency

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14 FreeSpace did not participate in this proceeding during the formal comment period.

15 *See supra* note 2.

16 *Ex Parte Letter of Charles W. Logan,* October 5, 1999, enclosure.

coordination with public safety entities was critical, FreeSpace blithely reversed its position on frequency coordination. Originally, viewing coordination as "cumbersome, inefficient and, at times, ineffective,"[17] FreeSpace nonetheless completely reversed course to "embrace frequency coordination as an effective technique to avoid and resolve interference."[18] Whatever FreeSpace thinks its audience wants to hear, it will agree to.

Perhaps this agreement comes so readily because FreeSpace's proposal seems to exist only in the theoretical and its equipment exists only on paper:

- As far as can be determined, FreeSpace has never manufactured and deployed *any* equipment – not one single piece – much less equipment capable of satisfying the critical interference requirements it has so freely accepted.

- In particular, FreeSpace has never manufactured and deployed equipment capable of and intended for frequency and operational coordination – a process that FreeSpace a few weeks ago found too "cumbersome" to perform.

- Remarkably, as far as can be determined, none of the claims that FreeSpace has made about its ability to protect public safety systems has been tested in any way. FreeSpace has not submitted the results of any field tests or even a simulation of its interference mitigation techniques. As far as can be determined, FreeSpace does not even hold an experimental license from the Commission so that it *could* conduct equipment tests.

- Unlike the other participants in this proceeding, FreeSpace failed to subject its plans to the Commission's notice and comment process. In fact, FreeSpace did not participate in the comment rounds in this proceeding and first surfaced on October 5, 1999 – more than two months after the comment period had expired. Since then, it has engaged in endless rounds of free-floating *ex parte* submissions.

FreeSpace asks the Commission to conclude that this company's unproven and untested technology and its ever-evolving positions would "ensure" the protection of

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17 *Ex Parte Letter of Charles W. Logan,* October 13, 1999.

18 *Ex Parte Letter of Charles W. Logan,* December 17, 1999.

adjacent public safety operations – as required by Congress. Motorola submits that FreeSpace's *ex parte* filings in this proceeding provide no basis for any such conclusion.

This is not to say that FreeSpace's proposed system could not operate successfully in other bands more suitable to its technical characteristics. In fact, several other spectrum options would appear to exist for FreeSpace including the remaining 30 MHz of this commercial allocation. Also, the FCC has some 300 MHz of unlicensed spectrum available in the 5 GHz band allocated precisely for wireless internet access. Finally, the recent FCC Policy Statement on spectrum management identifies more than 60 MHz that will soon be made available for flexible fixed and wireless services.[19] The public safety guard bands, however, are simply not appropriate for the FreeSpace technology.

* * *

Public safety guard bands are a dangerously poor venue for experimentation. Public safety communications – by police and fire departments, ambulances, disaster relief units – must go through, and interference to those signals quite literally endangers lives and property. There is widespread confirmation of existing interference in other bands caused by the same scenarios being discussed here today.[20] That is why Congress instructed the Commission to "ensure" non-interference with public safety communications.

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[19] *In the Matter of Principles for Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millennium,* FCC No. 99-354, *Policy Statement,* released November 22, 1999.

[20] *See, e.g.,* Comments of Arizona Department of Public Safety, WT Docket No. 99-168, submitted November 17, 1999; Comments of Maryland State Police, WT Docket

Accordingly, Motorola respectfully requests the Commission adopt rules that "ensure" that any potential uses of the subject guard bands be proven to provide interference protection to public safety systems operating between 764-776 and 794-806 MHz. As Motorola has demonstrated, cellular-like infrastructures operating within the defined guard bands offer a high probability of interference to such public safety systems. Far from ensuring their protection, deployment of such systems will result in a decreased availability of spectrum for critical public safety uses.

Respectfully submitted,
MOTOROLA

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January 18, 2000
Attachment

No. 99-168, submitted October 28, 1999.

APPENDIX A

Motorola Responses to Specific FCC Questions on the Operational and Technical Characteristics of Systems Using the 700 MHz Guard Bands

1. What out-of-band emission (OOBE) limits should the Commission apply to licensees operating in the guard bands to protect public safety?

The philosophy which Motorola espouses for the guard bands is to create rules which allow only services which are substantially similar to public safety systems to operate in the bands. Therefore, Motorola believes that the out-of-band emission limits which should apply to the guard bands should be the same as those which apply to the public safety bands themselves. Identical emission characteristics as well as similar deployment scenarios, combined with frequency coordination, will result in the dividing lines between the public safety allocations and the guard bands (764 MHz, 776 MHz, and 794 MHz) being essentially regulatory dividing lines only. From a technology point of view, there will be no transition from one technology to another and, therefore, no interference.

2. For instance, should licensees operating in the guard bands be required to: (1) comply with the Adjacent Channel Coupled Power (ACCP) OOBE limits that were adopted for 700 MHz public safety operations and (2) implement frequency coordination procedures with the designated public safety coordinators?

As stated in the answer to the first question, Motorola believes that this is precisely the correct approach to "ensure" non-interference to public safety users. The guard band operations should be required to satisfy all of the requirements of the public safety operations, including the frequency coordination obligations.

3. Should the Commission restrict operation in the guard bands to those entities that would not use an architecture that employs an intense, cellular-like frequency re-use pattern? Alternatively, should there be different OOBE and/or frequency coordination rules applicable to such systems?

Rules for the guard band spectrum should be specifically designed to restrict substantially dissimilar services from occupying the spectrum adjacent to public safety. Intense, cellular-like reuse patterns will result in a great number of interference locations within each public safety coverage area which need to be resolved. The logic of creating a guard band dictates that as much care as possible be taken to guard the public safety systems from interference from the guard band itself. Allowing architectures which will, by their very nature, create tens or hundreds of interference zones is not a reasonable approach. Therefore, they should be restricted.

The basis for Motorola's response to this question is further detailed in Attachment 1 to this Appendix. Attachment 1 provides qualitative and quantitative analyses on the harmful effects that can be predicted to exist should cellular-like architectures be permitted to deploy in the guard bands.

4. To the extent no restrictions are placed on the nature of the system architecture of the licensee operating in the guard bands, what other limitations should be placed on licensees because of the important need to protect public safety? For example, should the Commission require equipment in the guard bands not only to meet the same OOBE limits required of equipment operating in the 30 MHz spectrum, but also to frequency coordinate? What form should such frequency coordination take? As another example, should such equipment in the guard band be subject to higher OOBE limits than required of equipment operating in the 30 MHz spectrum? If so, would frequency coordination be necessary?

Motorola does not believe that it makes sense to attempt to create rules for the guard band spectrum which run counter to the weight of evidence which exists on how to correct and avoid interference scenarios. The creation of the guard bands is premised on the idea of providing the maximum protection possible to public safety operations. This can be done by examining real-world examples of interference and applying the lessons they teach us. Primary among those lessons is that dissimilar services should be separated from each other geographically when possible, and spectrally when not. Attempting, instead, to fashion new rules to protect public safety operations is to treat this important problem as though it were a trivial matter of little consequence rather than a decision which could have life or death implications for public safety officers in the future. The Commission's actions to date demonstrate that the agency does not take its legal responsibilities so lightly.

ATTACHMENT TO APPENDIX A

Interference From Cellularized Commercial Systems Into Public Safety Systems

Motorola

January 18, 2000

Interference From Cellular-Like Systems Into Public Safety Systems

In comments previously filed, Motorola has stated that, since the purpose of the guard bands is to protect Public Safety operations from interference, the systems authorized for use in the guard bands should not be of a type which will cause harmful interference to Public Safety. We have also stated that systems that deploy cells using a typical "cellular reuse" pattern to cover a wide area will present an interference problem for Public Safety systems. In this appendix we will describe why this is the case.

Depending on how the technologies in the guard bands are deployed there will be different types of interference events. However, the events will comprise one or more of the following types.

- Guard Band base station transmitters into Public Safety mobile receivers ($GB_{BS} \to PS_{MS}$)
- Guard Band base station transmitters into Public Safety base receivers ($GB_{BS} \to PS_{BS}$)
- Guard Band mobile station transmitters into Public Safety mobile receivers ($GB_{MS} \to PS_{MS}$)
- Guard Band mobile station transmitters into Public Safety base receivers ($GB_{MS} \to PS_{BS}$)

The base transmit and mobile transmit bands for the Public Safety operations have already been defined. Base station transmission takes place in the 764-776 MHz band, and mobile station transmit takes place in the 794-806 MHz band. The FCC's recent decision on 30 MHz of the commercial spectrum in the 746-806 MHz band creates rules which anticipate similar operation in those bands. Assuming similar operation in the guard bands, we have the following interference boundaries, as shown in Figure 1.

- $GB_{BS} \to PS_{MS}$ at 764 MHz
- $GB_{MS} \to PS_{MS}$ at 776 MHz
- $GB_{MS} \to PS_{BS}$ at 794 MHz

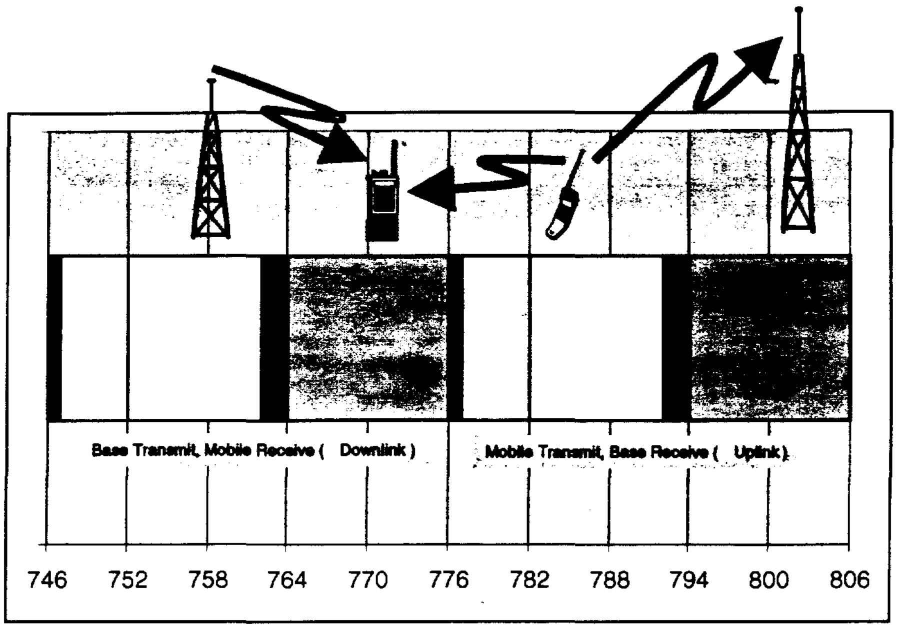

Figure 1: 700 MHz Band Plan And Anticipated Interference Scenarios

Some or all of these scenarios will exist whether or not the guard bands are used for base and mobile transmissions in precisely this manner. In reviewing the effects of these scenarios, we will use the same methodology as used by the National Telecommunications and Information Agency (NTIA) in this proceeding.

The power of an interfering signal in a Public Safety receiver can be found by starting with the radiated power of the interfering signal, attenuating it to account for its out-of-band emissions characteristics and cable loss, and including the effects of the gain of the transmitting and receiving antennas and the propagation loss. Mathematically this is expressed as in equation (1)

$$I = P_T - P_{OOB} - L_T + G_T - L_P + G_R - L_R \qquad \text{(Eq. 1)}$$

where

$I =$ interfering signal power level at receiver input (dBm or dBW)

$P_T =$ interfering signal power level of the commercial transmitter (dBm or dBW)

$P_{OOB} =$ attenuation of the out-of-band emissions of the commercial transmitter (dB)

$L_T =$ cable/filtering/combiner loss of commercial transmitter (dB)

$G_T =$ commercial transmitter antenna gain (dBi)

$L_P =$ propagation loss between the commercial'l transmitter and the Public Safety receiver (dB)

$G_R =$ Public Safety receiver antenna gain (dBi)

$L_R =$ cable/insertion loss of the Public Safety receiver (dB)

These relationships are shown graphically in Figure 2.

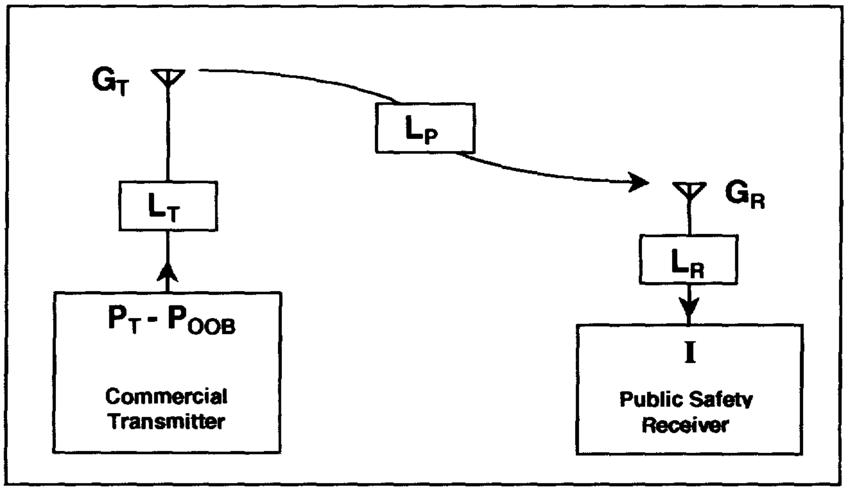

Figure 2: Commercial Transmitter to Public Safety Receiver Path

When an allowable interfering signal power level is determined, the rest of the parameters in this expression can be estimated so as to obtain the required propagation loss. This is shown in equation 2.

$$L_P = P_T - P_{OOB} - L_T + G_T + G_R - L_R - I \qquad \text{(Eq. 2)}$$

Finally, this path loss can be converted into a distance using the expression for modified free space path loss between two antennas with gains relative to isotropic point sources (the reason for quoting the antenna gains, above, in dBi).

$$20\log(D_{sep}) = L_P - 20\log f - 32.45 - L_{clutter} \qquad \text{(Eq. 3)}$$

where

D_{sep} = distance separation between the commercial transmitter and the Public Safety receiver

L_P = propagation loss between the commercial transmitter and the Public Safety receiver

f = frequency of the commercial transmitter (MHz)

$L_{clutter}$ = factor to account for the fact that the path loss is greater than free space path loss because of the effects of local "clutter"

Commercial Base Into Public Safety Mobile Receiver Interference

In the geographic area around a commercial base station a Public Safety radio will not be able to receive the transmissions from its own base station. This is known as a coverage "hole". Qualitatively, the reason for this is the following. If the commercial base station is not at the same geographic location as the Public Safety base station, the desired signal from the Public Safety base station reaching the Public Safety radio receiver will be attenuated due to the effects of path loss. If the receiver is in close proximity to a commercial base station, even the out-of-band emissions from that base station which pass into the Public Safety receive band can be large enough to disrupt communications.

The magnitude of the effect depends on a number of factors. First, it depends on the magnitude of the out-of-band emissions. If those emissions are large, they will more easily mask the desired signal. Second, it depends on the signal strength of the desired signal. If the signal is very weak, it is easier for the interferer to disrupt it. The only protection that the Public Safety radio has from this interfering signal is geographical separation from the source, so that, due to path loss, the absolute level of the interfering signal received by the Public Safety radio will be low enough to allow communications to occur.

The practical result of this is that, in the area directly around the interfering base site, communications will be disrupted. At some distance away from the interfering base site, the Public Safety communications will not be completely disrupted, but they will be degraded in quality. And at some distance beyond that, there will be no disruption or degradation. The size of the disrupted area is related to the desired signal's receive strength, so the effect is greatest in the weak signal areas. These are areas which are either far from the Public Safety base station, or areas in which the desired signal has been attenuated by, for example, terrain blockage, foliage, building penetration, etc. In short, interference effects will be greatest in areas of "fringe" coverage of the Public Safety system.

A qualitative representation of this effect is shown in figure 3. (The figure is "qualitative" because the interference zones shown in the figure are for illustrative purposes only. They are not to scale and do not represent the results of an interference calculation. A quantitative discussion follows this qualitative illustration.)

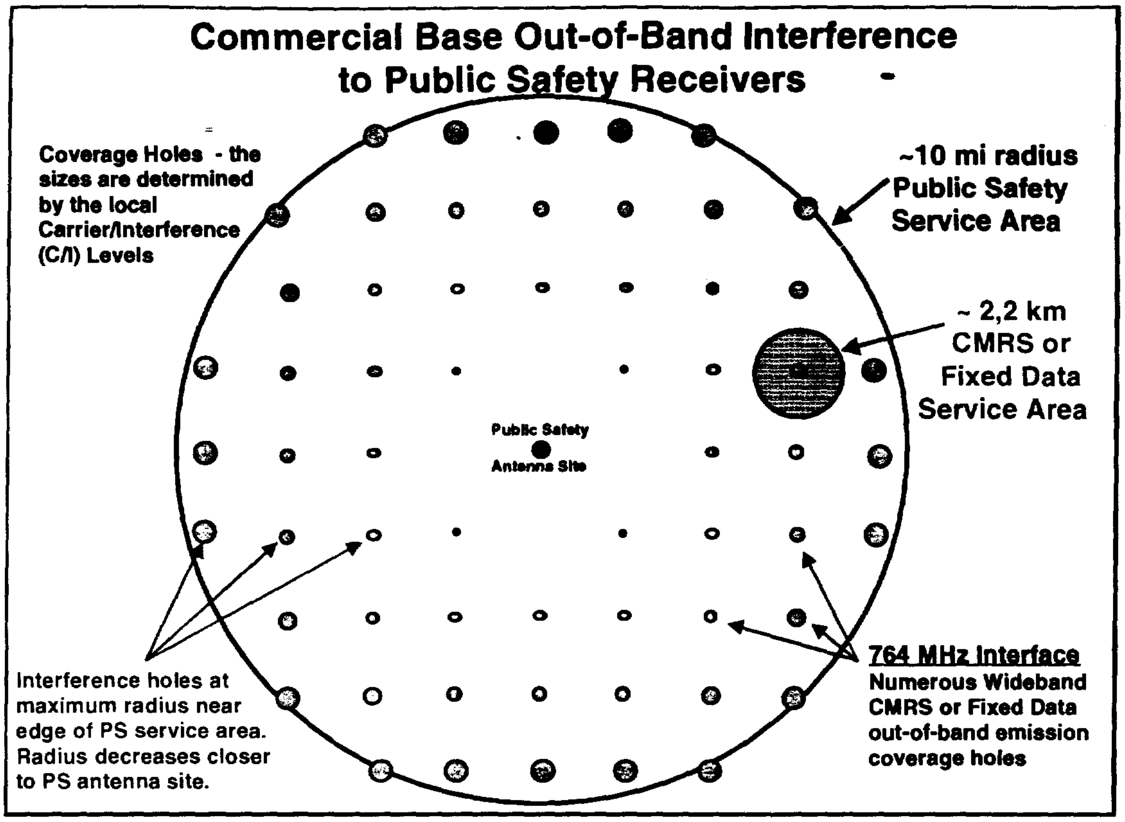

Figure 3: Qualitative Illustration Of The Effect Of Interfering Base Stations Distributed Within The Public Safety Coverage Area

In this figure the Public Safety antenna site is located at the center of the circle, and the solid border of the large circle indicates the edge of the Public Safety coverage area. A representative number for the radius of coverage of a Public Safety base site is 10 miles, or approximately 16 km. Each of the small circles in this diagram represents the location of a base station which is part of a system deployed using a cellular-reuse hexagonal pattern to cover this same area. A representative radius of coverage for one of those sites is 2.2 km. The number of commercial sites needed to cover the same area when deployed in this fashion is approximately

$$(R_{PS} / R_{commercial})^2 = (16^2 / 2^2) = 64$$

Each of the small circles represents the coverage hole which will exist around the commercial transmitters. Within the area defined by these circles, the Public Safety subscriber units will not be able to operate correctly. Using the values in the above example, there would be on the order of 64 such coverage holes within this Public Safety coverage area.

In order to understand the magnitude of this effect, a quantitative estimate of the size of each of these coverage holes can be made using equations 1-3, above. We first proceed with an analysis with antenna network gains and losses set to 0.

$$G_T = 0 \text{ dBi}$$
$$G_R = 0 \text{ dBi}$$
$$L_T = 0 \text{ dB}$$
$$L_R = 0 \text{ dB}$$

As Motorola has stated previously in this proceeding, the level of interference appropriate for mission-critical Public Safety operations is 6 dB below the noise floor of the radio. This level will cause a rise in the noise floor of 1 dB. For a 6.25 kHz bandwidth receiver, the thermal noise floor is at –136 dBm. A typical receiver noise figure is in the 8 to 10 dB range. This means the receiver internal noise floor is in the –126 to –128 dBm range, which closely matches levels stated previously in this proceeding. Therefore, a reasonable value for *I* which can be used in these equations is:

$$I = -126 \text{ dBm} - 6 \text{ dB} = -132 \text{ dBm} \ (-162 \text{ dBW})$$

In order to estimate the out of band emissions from the interfering transmitter, we can take as representative the rules which the FCC has just adopted for out-of-band emissions from equipment operating in the 30 MHz of spectrum in this band. As stated in the new rule section 27.53(c)(2), for operations in the 747 to 762 MHz band (the base transmit band), the power of any emission outside the licensee's frequency band of operation shall be attenuated below the transmitter power (P) within the licensed band(s) of operation, measured in watts by a factor not less than 76 + 10 log (P) dB in a 6.25 kHz band segment. Taking this as our model, it is not necessary to specify P_T, the power of the commercial transmitter. Under section 27.53(c)(2), the value of out-of-band emissions, $P_T - P_{OOB}$, is defined to be less than or equal to –76 dBW in a 6.25 kHz bandwidth.

Equation 2, therefore, becomes

$$\begin{aligned} L_P &= (P_T - P_{OOB}) - L_T + G_T + G_R - L_R - I \\ &= (-76dBW) - 0dB + 0dBi + 0dBi - 0dB - (-162dBW) \\ &= 86dB \end{aligned}$$

With a required propagation loss of 86 dB, equation 3 can be used to find the distance from the base station which is required to achieve that path loss. With the frequency and clutter factor defined to be

$$f = 764MHz$$
$$L_{clutter} = 5dB$$

the separation distance is

$$\begin{aligned} 20\log(D_{sep}) &= L_P - 20\log f - 32.45 - L_{clutter} \\ &= 86dB - 57.66 - 32.45 - 5 \\ &= -9.11 \end{aligned}$$

which leads to $D_{sep} = 0.350km$, or 350 meters. In other words, there will be a Public Safety coverage hole anywhere within 350 meters of the commercial base site. All Public Safety mobile receivers within this distance will receive interference from the site at a level greater than the level which is appropriate for the protection of Public Safety radios.

As emphasized by NTIA in its analysis of this subject, the effect of gain in either the commercial base station transmitting antenna network or the Public Safety receiving antenna network will influence the required separation distance. Figure 4 uses this same analysis while varying the antenna network gain and loss factors, $(G_T - L_T) + (G_R - L_R)$, to show the effect of antenna gain on these coverage holes.

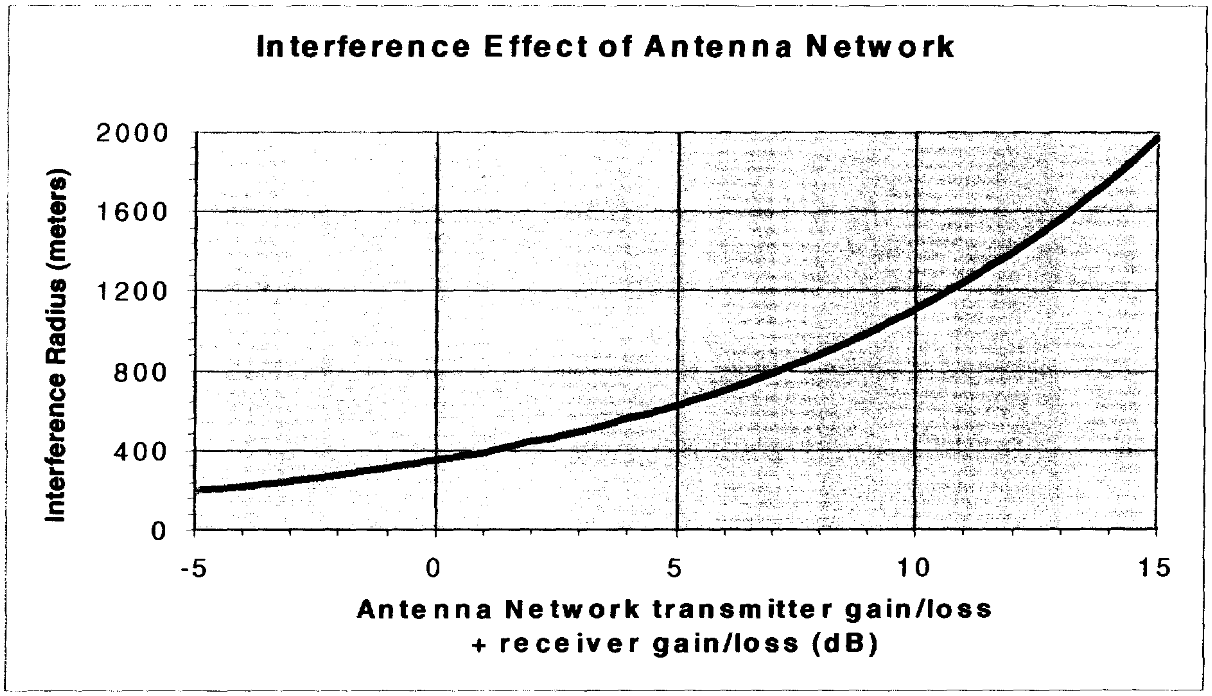

Figure 4: The Increasing Effect Of Transmitter And Receiver Gain On The Interference Range Around Interfering Base Stations

Using the same assumptions above (64 commercial base sites within the coverage area of a single Public Safety site) the area outage can be estimated as follows.

$$\text{Fractional Outage} = \frac{64 \times \pi R_{sep}^2}{\pi R_{PS}^2}$$

With a Public Safety area of 16 km in radius and a separation distance from the commercial base transmitter of 0.350 km, the fractional outage using the above expression is found to be 0.0307, or 3.07%. This means that, for this example, an area of 24.7 square kilometers (9.5 square miles) will be subjected to interference beyond the target level. It is highly probable that the transmitter sites will incorporate antennas with gain as well. Transmitter gains can have an extremely significant impact on the coverage area receiving interference above the desired level. As can be seen in Figure 5, when the gain reaches 15 dBi, all of the Public Safety coverage area will be subjected to interference above the desired level.

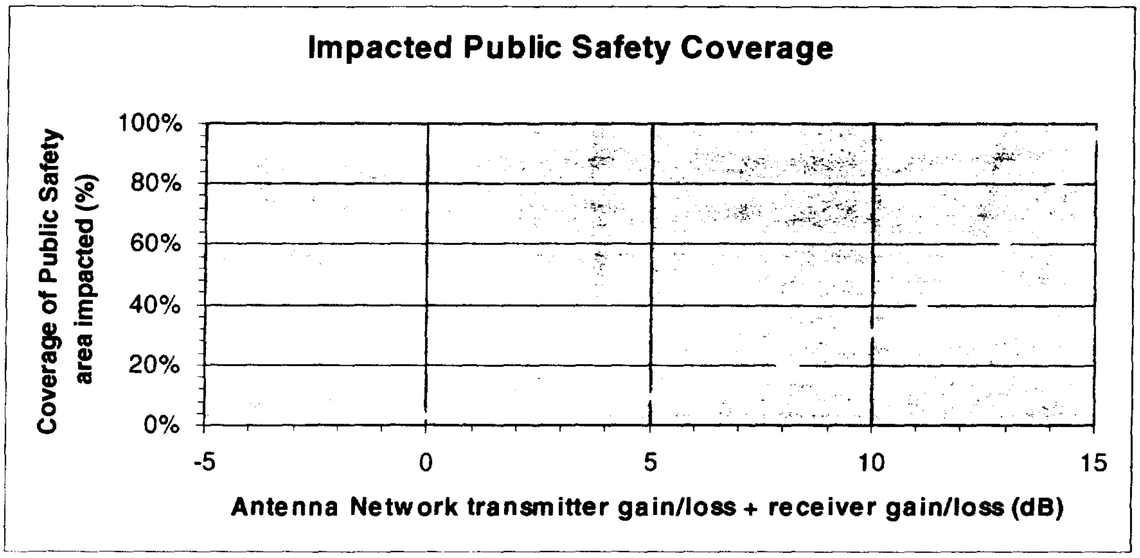

Figure 5: Percentage Of The Public Safety Coverage Area Receiving Interference Above The Target Level

The severity of the impact of this base station to subscriber station interference will depend on the relative signal strengths of the Public Safety signal and the interfering signal. In this example, we have assumed that the strength of the Public Safety signal diminishes as a function of the distance from the base station as described by equation 3. We can define the edge of coverage to be the point at which there is no margin for interference; that is, any interference above the target level will be harmful to communications. So at this distance from the Public Safety base site the Public Safety mobile unit must be the maximum distance (350 meters in the current example) away from the commercial base site in order to avoid harmful interference. As we move in from the edge of coverage, the desired signal from the Public Safety base site will increase in strength, providing additional protection against interference. Therefore, the Public Safety mobile unit can get closer than 350 meters to the commercial base site and still maintain sufficient communications link quality. This effect is shown qualitatively by the size of the interference areas shown in Figure 3 (they decrease as one moves toward the Public Safety base site). A quantitative analysis is shown in Table 1.

Radius (km)	Margin (dB)	Required Propagation Loss (dB)	Separation Distance (m)
16	0.00000	86.00000	354.44842
15	0.56057	85.43943	332.29540
14	1.15984	84.84016	310.14237
13	1.80353	84.19647	287.98934
12	2.49877	83.50123	265.83632
11	3.25455	82.74545	243.68329
10	4.08240	81.91760	221.53026
9	4.99755	81.00245	199.37724
8	6.02060	79.97940	177.22421
7	7.18044	78.81956	155.07119
6	8.51937	77.48063	132.91816
5	10.10300	75.89700	110.76513
4	12.04120	73.95880	88.61211
3	14.53997	71.46003	66.45908
2	18.06180	67.93820	44.30605
1	24.08240	61.91760	22.15303

Table 1: Public Safety Mobile To Commercial Base Separation Distances Required As A Function Of Distance From The Public Safety Base Station

Since there will be more commercial base sites far from the Public Safety base site (there is more area in an annulus far from the site than there is in an annulus with the same depth near to the site), it is appropriate to use weighting to calculate the average of these separation distances. We define the weighted average as in the following expression.

$$D_{sep(weighted)} = \sum\left(D_{sep} \times Radius\right) \Big/ \sum Radius \qquad \text{(Eq. 4)}$$

For this example, this leads to a weighted average separation distance of 243 meters. This results in an outage estimation of 1.5%, which, in this example, is 11.9 km^2 (4.6m^2).

Commercial Subscriber Into Public Safety Mobile Receiver Interference

An analysis similar to that above can be performed for the case of commercial mobile station interference into the Public Safety mobile receivers. As shown in figure 1, this is a particular problem at the 776 MHz interface.

Qualitatively the effect is similar to that discussed above, but it is caused by the commercial subscriber units. This is even a more insidious problem because there is no way of knowing where those units will be located. A general observation can be made, however, that typically commercial systems concentrate on providing coverage in locations where there are a large number of potential users, such as major roads, apartment buildings, stadiums, and municipal locations. Major events, such as disasters, also tend to draw crowds of users of commercial wireless systems. All of these locations are the types of locations where Public Safety officers need to be able to operate.

As in the base station to mobile receiver example, the effect is magnified in the fringe areas where the desired signal from the Public Safety transmitter is weakest. Figure 6 uses the same configuration as discussed previously (64 commercial sites within a Public Safety coverage area) and qualitatively illustrates this problem.

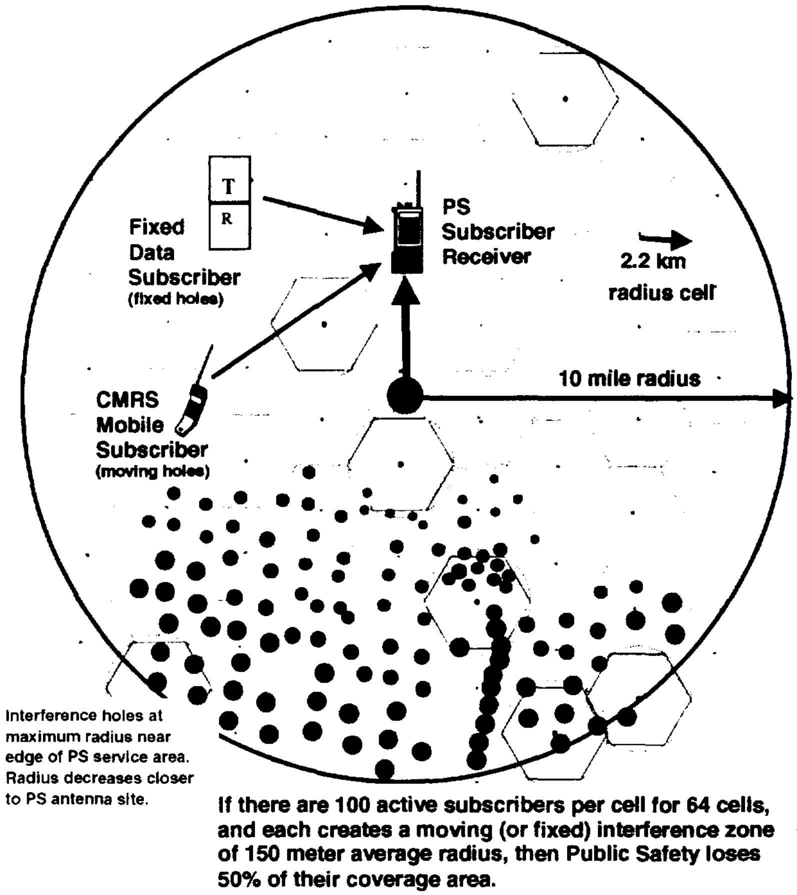

Figure 6: Qualitative Illustration Of The Effect Of Commercial Subscriber Units In The Guard Bands Creating "Moving" Interference Holes In The Public Safety Coverage Area

Figure 6 shows a cellular re-use architecture overlaid on a wide-area Public Safety service area. The commercial subscribers might be CMRS telephones creating moving coverage holes. The commercial subscribers might be fixed data subscribers creating fixed coverage holes. Again, hole size varies from large at the fringe of the Public Safety service area to small near the Public Safety antenna site. Hole size also varies within each cell. As power control is implemented, larger holes occur at the fringe of each cell, and smaller holes occur near cell site, because the commercial subscriber units will need higher power when far from their own cell sites, and lower power when closer. Terrain blockage, building penetration loss, foliage, and any other obstruction that lowers the level of the desired Public Safety signal affects the size of these coverage holes. With fixed data interfering subscribers, the antenna mounting height of the data unit on the sides of buildings will affect the size of the coverage hole. The higher the antennas are mounted, the larger the holes will be.

The quantitative analysis carried about above can be repeated for this case. We can again take as representative the rules which the FCC has just adopted for out-of-band emissions from equipment operating in the 30 MHz of spectrum in this band. As stated in the new rule section 27.53(d)(2), for operations in the 777 to 792 MHz band (the mobile transmit band), the power of any emission outside the licensee's frequency band of operation shall be attenuated below the transmitter power (P) within the licensed band(s) of operation, measured in watts by a factor not less than 65 + 10 log (P) dB in a 6.25 kHz band segment. The value of out-of-band emissions, $P_T - P_{OOB}$, is then defined to be less than or equal to – 65 dBW in a 6.25 kHz bandwidth.

Equation 2, therefore, becomes

$$\begin{aligned} L_P &= (P_T - P_{OOB}) - L_T + G_T + G_R - L_R - I \\ &= (-65dBW) - 0dB + 0dBi + 0dBi - 0dB - (-162dBW) \\ &= 97dB \end{aligned}$$

With a required propagation loss of 97 dB, equation 3 can be used to find the distance from the mobile station which is required to achieve that path loss. For mobile-to-mobile propagation we can increase the clutter factor, so we have

$$\begin{aligned} f &= 776MHz \\ L_{clutter} &= 10dB \end{aligned}$$

This leads to a separation distance of

$$\begin{aligned} 20\log(D_{sep}) &= L_p - 20\log f - 32.45 - L_{clutter} \\ &= 97dB - 57.80 - 32.45 - 10 \\ &= -3.25 \end{aligned}$$

which leads to $D_{sep} = 0.688km$, or 688 meters.

An estimation of the coverage area lost due to this level of interference can be made in the following way. We estimate the number of users per square mile, estimate the penetration rate of the commercial system into that population, and estimate the fraction of those users who will be active at any given time (the duty cycle).

$$\text{Active Users } (/\text{mi}^2) = \text{Pop } (/\text{mi}^2) \times \text{Penetration rate} \times \text{Duty cycle}$$

We examined some medium and large cities in order to choose a reasonable value for the population density. According to 1990 census data, the population density for St. Louis is 6405.6/ mi^2, the population density for Washington, D.C. is 9882.6/ mi^2, and the population density for Chicago is 12,252.3/ mi^2. Using a conservative population density of 2000 people/ mi^2, a penetration rate of the technology into this population of 10%, and a duty cycle of 10%, we find

$$\begin{aligned}\text{Active Users } (/\text{mi}^2) &= 2000 \ (/\text{mi}^2) \times 0.1 \times 0.1 \\ &= 20(/\text{mi}^2)\end{aligned}$$

In the above example, the radius of coverage of the commercial base station is 2.2 km (1.374 miles), so the area covered by a hexagonal cell is $2.6 \times R^2 = 4.9$ mi^2. This means that in each cell, the number of active users at any given time is

$$\text{Active Users (per commercial cell)} = 4.9 \text{ mi}^2 \times 20/ \text{ mi}^2 = 98 \text{ users}$$

Since there are 64 commercial cells inside the Public Safety coverage area, the fractional outage due to this number of users creating outage holes of 688 meters in radius is

$$\begin{aligned}\text{Fractional Outage} &= \frac{N_{cells} \times (N_{users} / cell) \times \pi R^2_{outage}}{\pi R^2_{PS}} \\ &= \frac{64 \times 98 \times \pi \times 0.688^2}{\pi \times 16^2}\end{aligned}$$

=11.6 or 1160%

As we have done previously for the base station to mobile station interference scenario, we can estimate the fraction of the Public Safety coverage area over which there would be interference harmful to communications. As before, the fringe is defined to be the point at which there is zero margin for harmful interference, and propagation losses and resulting distances are found. In this case, however, we also include an extra 10 dB of margin to account for the fact that power control on the commercial mobile stations can help to limit the interference potential of these units. The resulting interference holes around the commercial subscriber units are shown in table 2. The decreasing separation distance is illustrated in figure 6 by the tendency of the interference holes to shrink in size as they approach the Public Safety base site.

Radius (km)	Margin (dB)	Required Propagation Loss (dB)	Separation Distance (m)
16	10.00000	87.00000	217.58967
15	10.56057	86.43943	203.99032
14	11.15984	85.84016	190.39096
13	11.80353	85.19647	176.79161
12	12.49877	84.50123	163.19225
11	13.25455	83.74545	149.59290
10	14.08240	82.91760	135.99355
9	14.99755	82.00245	122.39419
8	16.02060	80.97940	108.79484
7	17.18044	79.81956	95.19548
6	18.51937	78.48063	81.59613
5	20.10300	76.89700	67.99677
4	22.04120	74.95880	54.39742
3	24.53997	72.46003	40.79806
2	28.06180	68.93820	27.19871
1	34.08240	62.91760	13.59935

Table 2: Public Safety Mobile To Commercial Mobile Separation Distances Required As A Function Of Distance From The Public Safety Base Station

As can be seen, including this extra 10 dB of protection reduces the separation distance at the fringe from 688 meters to 217 meters. Using the same weighting as discussed earlier in equation 4, the weighted average separation distance for the mobile to mobile interference case is found to be 150 meters. This results in an outage estimation of 55%, which, in this example, is 443 km^2 ($171 m^2$).

Commercial Subscriber Into Public Safety Base Receiver Interference

When commercial subscriber out-of-band emissions interfere with Public Safety base station receivers, the Public Safety base receiver will not be able to receive the transmissions from its own Public Safety subscribers located at the fringe of the Public Safety service area. This results in, effectively, a reduction in the area covered by the Public Safety base station. Qualitatively, the reason for this is the following. The desired signals from fringe area Public Safety subscribers reaching the Public Safety base receiver will be attenuated due to the effects of path loss. If the commercial mobile or fixed subscribers are in close proximity to the Public Safety base receiver site, the out-of-band emissions from those commercial subscribers which pass into the Public Safety receive band can be large enough to mask or distort the weak, but desired, Public Safety signals.

As in the previously discussed cases, the effect on the Public Safety communications will depend on the magnitude of the out-of-band emissions and the signal strength of the desired Public Safety signal. So, as previously, the practical result of this interference is that communications from the fringe of the Public Safety service area will be affected. In a simple model this fringe is the annulus of coverage far from the Public Safety base station. At a distance somewhat closer to the Public Safety base site, the Public Safety communications will not be completely disrupted, but they will be degraded in quality. And at some distance closer, there will be no disruption or degradation

A qualitative representation of this effect is shown in figure 7. (The figure is "qualitative" because the interference zones shown in the figure are for illustrative purposes only. They are not to scale and do not represent the results of an interference calculation. A quantitative discussion follows this qualitative illustration.)

As shown in figure 1, this particular problem occurs at the 794 MHz interface. Figure 7 uses the same configuration as discussed previously (64 commercial sites within a Public Safety coverage area).

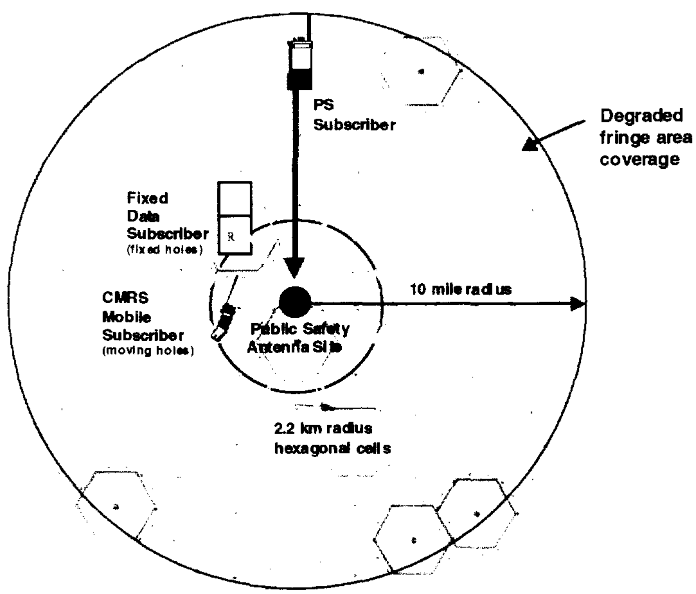

Figure 7: Qualitative Illustration Of The Effect Of Commercial Subscriber Units In The Guard Bands Reducing The Public Safety Coverage Area

The quantitative analysis carried out for the other scenarios can be repeated for this case. We again take as representative the rules which the FCC has just adopted for out-of-band emissions from equipment operating in the 30 MHz of spectrum in this band. As stated in the new rule section 27.53(d)(2), for mobile operations in the 777 to 792 MHz band the power of any emission outside the licensee's frequency band of operation shall be attenuated below the transmitter power (P) within the licensed band(s) of operation, measured in watts by a factor not less than 65 + 10 log (P) dB in a 6.25 kHz band segment. The value of out-of-band emissions, $P_T - P_{OOB}$, is then defined to be less than or equal to – 65 dBW in a 6.25 kHz bandwidth.

We first proceed with an analysis with antenna network gains and losses set to 0.

$G_T =$ 0 dBi
$G_R =$ 0 dBi
$L_T =$ 0 dB
$L_R =$ 0 dB

Equation 2, therefore, becomes

$$\begin{aligned} L_P &= (P_T - P_{OOB}) - L_T + G_T + G_R - L_R - I \\ &= (-65dBW) - 0dB + 0dBi + 0dBi - 0dB - (-162dBW) \\ &= 97dB \end{aligned}$$

With a required propagation loss of 97 dB, equation 3 can be used to find the distance from the base receiver which is required to achieve that path loss. For mobile-to-base propagation we use a lower value for the clutter factor, so we have

$$f = 794MHz$$
$$L_{clutter} = 5dB$$

This leads to a separation distance of

$$\begin{aligned} 20\log(D_{sep}) &= L_P - 20\log f - 32.45 - L_{clutter} \\ &= 97dB - 58.0 - 32.45 - 5 \\ &= 1.55 \end{aligned}$$

which leads to $D_{sep} = 1.195km$, or 1195 meters. That is, commercial subscribers operating within 1.2 km of the Public Safety base site will degrade Public Safety fringe area coverage.

However, Public Safety base receiver antenna gain G_R is not 0 dBi and base receiver line loss L_R is not 0 dB. Typical Public Safety antenna gain is in the range of 5 to 8 dBi. The typical base receiver antenna network for trunked systems has an amplifier to overcome line losses and improve portable fringe area coverage. Typical base receive loss is actually a gain of 1 to 6 dB.

If we revisit the previous analysis setting

$G_T =$ 0 dBi
$G_R =$ 8 dBi
$L_T =$ 0 dB
$L_R =$ -1 dB (gain of +1 dB)

we find that the required separation distance is $D_{sep} = 3.369km$, or 3,369 meters. That is, commercial subscribers operating within 3.37 km of the Public Safety base site will degrade Public Safety fringe are coverage.

If, on the other hand, we assume that the subscriber units will be part of a fixed data system operating in the guard band, we need to adjust the parameters to reflect the higher antenna heights and and higher ERP typical of these systems. Fixed data antenna gain will vary from 0 dBi to 6 dBi . Fixed data antennas mounted on the sides of buildings and on utility poles will have effective antenna gain increased by 6 to 12 dB. On the other hand, for fixed data subscribers it is more appropriate to estimate the out-of-band emissions using the new rule section 27.53(d)(3), which requires attenuation "by a factor not less than 76 + 10 log (P) dB in a 6.25 kHz band segment, for fixed stations transmitting in the 777 to 792 MHz band." Revisiting the analysis with these parameters yields the following result.

$G_T =$ 6 dBi
$G_R =$ 8 dBi
$L_T =$ 0 dB
$L_R =$ -1 dB (gain of +1 dB)

Equation 2, therefore, becomes

$$\begin{aligned} L_P &= (P_T - P_{OOB}) - L_T + G_T + G_R - L_R - I \\ &= (-76dBW) - 0dB + 6dBi + 8dBi - (-1)dB - (-162dBW) \\ &= 101dB \end{aligned}$$

which leads to $D_{sep} = 1.905km$, or 1,905 meters. That is, commercial subscribers operating within 1.9 km of the Public Safety base site will degrade Public Safety fringe are coverage. Any increase in antenna height will increase the radius.

The results of these analyses indicate that the degradation of fringe coverage due to commercial subscriber units interfering with Public Safety base stations is also a cause for concern. Not only is the interference, depending on the specific situation, likely to be caused by subscriber units as far as 1 km from the Public Safety base site, but this interference is also additive. The above analyses examine interference from a single commercial subscriber. The interference power from multiple commercial subscribers operating simultaneously is added at the Public Safety base receiver, increasing the amount of interference and the amount of fringe area degradation.

Definition Of The Fringe

We have stated a number of times in this report that the interference events which occur between the commercial and Public Safety systems will be felt most strongly in the areas of fringe coverage. It is important to understand, however, that fringe coverage areas do not only occur at great distances from the Public Safety site. They occur whenever the desired signal from the Public Safety system is weak. Such a weak signal might be due to large distances, but it may also be caused by terrain blocking or building penetration.

This second point is extremely important. Over the past few years many Public Safety organizations have upgraded their systems to achieve coverage reliabilities in the range of 95%-97%, up from 90% reliability they designed to years ago. Much of the increased requirement has been in-building fringe coverage. The impact of the kinds of interference we are discussing here will be a loss of coverage in the areas which have the weakest coverage, and the inside of buildings, which the Public Safety community has recently worked so hard to cover, will be among the first places to be lost.

Recommendations

It is clear from this analysis that the interference potential from commercial systems deployed in a cellular-like pattern into the Public Safety bands is a real and immediate threat. The Commission should not allow these types of systems to be deployed in the guard band spectrum, of all places, the purpose of which is to guard Public Safety systems from harmful interference. The Commission should write rules which encourage the deployment of systems which will have the same type of layout as the Public Safety systems, so that the problem of multiple interference sites within the coverage area is eliminated. In addition, systems deployed in this fashion can use time-tested frequency coordination procedures to avoid or, if necessary, resolve interference situations if they occur.

APPENDIX B

Statements and Positions of FreeSpace Communications

The following represent various positions and views provided by FreeSpace since the conclusion of the formal comment and reply comment period in the Federal Communications Commission's proceedings in WT Docket No. 99-168.

1. October 5, 1999: In an *ex parte* presentation filed two months after the closing of the formal reply comment period, FreeSpace introduces itself, its technology and its "solution" to establish "transmit power limits in guard bands adjacent to public safety spectrum that will provide maximum interference protection to current and future public safety operations."

2. October 13, 1999. FreeSpace provides further details and states that "a guard band in which licensees must comply with low power spectral density limits ... would provide full interference protection to current and future public safety communications." While extolling the benefits of its proposal, FreeSpace characterizes frequency coordination procedures as "cumbersome, inefficient, and at times ineffective" and argues that power spectral density limits in the guard band "obviates any need" to "manage" or "coordinate" uses in the adjacent guard bands.

3. October 29, 1999. FreeSpace states that it low power guard bands around public safety spectrum is a "clear, effective way to protect both current and future public safety uses." In addition, FreeSpace states that its "system will comply with any out-of-band spurious emissions limits necessary to protect public safety operations." FreeSpace argues that its proposal is "superior to [the] private radio guard band proposal, which relies on coordination efforts rather than power limits." This is because "coordination is cumbersome and will not adequately protect future public safety facilities."

4. November 8, 1999. FreeSpace states that "[p]rotection to public safety operations ... is due to two factors: the use of the 1 MHz bands as guard bands separating public safety operations from high power mobile and fixed services, and the specification of in-band power spectrum density emissions limits."

5. November 15, 1999. Supporting the notion that its system is coordinatable, FreeSpace states that its system "will not use only a single frequency channel" but does not provide the minimum number of channels needed or the proposed channel bandwidth. In response to Motorola concerns about indoor base transmitters, FreeSpace responds that "With power control, indoor units will operate on power levels far below the proposed emission limits."

6. November 24, 1999. "Under FreeSpace's proposal, only licensed services would operate in the guard bands. As a licensee of these guard bands, FreeSpace would be committed to cooperating fully with the public safety community in the unlikely event potential interference concerns arise.

7. December 6, 1999. Two months after its initial *ex parte* filing, FreeSpace discloses its theoretical channel spacing of 300 kHz. Within a 1.5 MHz block of spectrum, FreeSpace indicates that it could deploy two channels having an excess bandwidth factor of 1.2. FreeSpace defines its modulation as "e.g., 16QAM".

9. December 14, 1999. Contrary to earlier statements that power spectral density limits in the guard band obviates any need to manage or coordinate uses in the guard bands, FreeSpace concedes that it would comply with: 1) power limits set forth in Motorola's proposed section 27.50(c), 2) out-of-band emissions limits set forth in Motorola's proposed section 27.53(e)-(h), and 3) frequency coordination procedures that Motorola has proposed for systems operating in the guard bands.

10. December 17, 1999. Although it earlier stated that frequency coordination was cumbersome, inefficient and ineffective, FreeSpace now reiterates that it "has proposed in a recent filing that commercial licensees of the 1.5 MHz guard bands adjacent to the public safety bands should be required to frequency coordinate with public safety frequency coordinators to maximize the protection from interference to public safety operations." FreeSpace further states, "By embracing frequency coordination as an effective technique to avoid and resolve interference concerns, the FreeSpace proposal would place the complete set of protection measures provided by frequency coordination at the service of the public safety the commercial entities occupying adjacent bands."

11. December 23, 1999. Despite earlier promises that indoor transmitters will operate with sufficiently low power, FreeSpace now clarifies that its "base units will be installed outdoors, in fixed, immobile locations."